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PROBABLE REPRESENTATIVES OF PRE-WISCONSIN TILL IN SOUTHEASTERN MASSACHUSETTS

INTRODUCTION

In the central portion of the country, where the glacial deposits are spread out in a general northward retreating series of sheets, the tills of the various ice invasions have long been differentiated and classified chronologically with a considerable degree of certainty. In New England, however, each of the prominent advances reached nearly or quite to the southern limit of the area. The repeated passage of the ice over the region, and the consequent severe glaciation to which it has been subjected, has served to remove far more thoroughly than in the region further west the evidences of pre-Pleistocene conditions and of early Pleistocene tills. Under such conditions of glaciation, the preservation of remnants of the early tills would be very exceptional, and it is not strange, therefore, that deposits of these early tills have not previously been found.

While severe glaciation is the rule in New England, the action has by no means been of the same severity throughout the area. The area may be divided into three parts: (1) a northern belt characterized by severe and almost universal erosion with correspondingly little deposition; (2) a middle belt with generally moderate, though sometimes locally severe glaciation, but characterized as a whole by a marked deposition of subglacial till as attested by its drumlins; and (3) a southern belt of generally weak erosion, except in the more exposed localities, accompanied by a comparatively slight deposition of till. This southern belt, the northern limit of which in eastern Massachusetts is a few miles south of Boston, is nearly or quite destitute of drumlins, rarely shows any evidences of severe glaciation such as characterizes the northern belt, and is marked by the occurrence of numerous instances of pre-glacially decayed rock surfaces.

It was while engaged in field work on the surface geology of

this southern belt that the writer first encountered exposures of till of a type entirely unlike that ordinarily prevailing over this part of New England. In composition, in color, and in weathering, the till in question was strikingly different from the ordinary buff till of the region, and had the aspect of being much older than the latter. A further study of its character and associations was found to corroborate the differences first noted, and apparently warranted the conclusion that it should be considered as representing the deposits of an ice sheet which certainly antedated the last invasion, and probably marked the earliest of the Pleistocene advances.

The area embracing these tills is located in the eastern and central portions of the Dedham quadrangle of the United States geological survey at a distance of some twenty miles south of the city of Boston. The position of the quadrangle and of the area of the till localities is shown in Fig. 1.

It will be seen from this map that the tills are situated some fifteen to twenty miles inside of the interlobate moraine near Plymouth, and at a distance of some fifty miles north of the line of the corresponding terminal moraine. This moraine, for in origin it is a unit, is usually correlated chronologically with the Wisconsin. If this is so, and there are apparently no grounds for doubting the conclusion, it is evident that the till sheet which covers the surface of this portion of Massachusetts to an average depth of perhaps five to fifteen feet, and which is clearly contemporaneous with the moraine, is likewise of Wisconsin age.

Observations on Massachusetts glacial deposits of an age earlier than those of the last ice advance have been few in number and, with the exception of occasional instances of the burial of stratified drift deposits beneath later tills, have been confined to the vicinity of the moraines along the south coast where the conditions for differentiating the glacial deposits are more favorable than in the inland area to the north.

Before considering the evidences of older tills which the writer believes he has discovered beneath the Wisconsin till sheet, mention will be made of a number of papers presenting

evidences of possible interglacial phenomena or of plural tills in this part of New England.

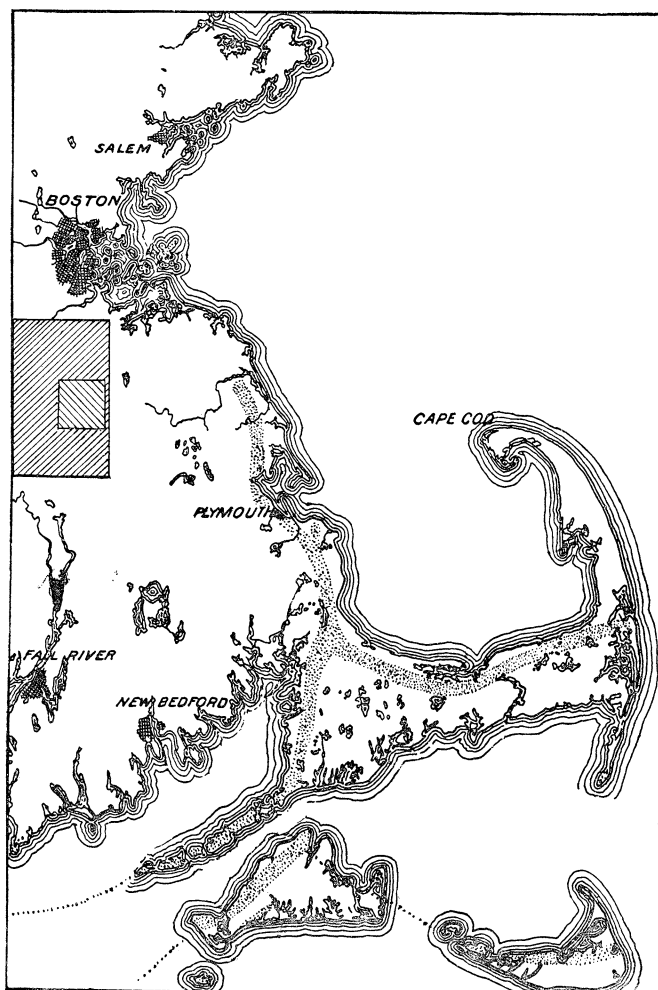


FIG. 1.—Sketch map of southeastern Massachusetts, showing the location of the Dedham quadrangle and of the special map of till localities (Fig. 2).

One of the first papers describing occurrences suggestive of interglacial deposits was that published by W. W. Dodge¹ in

¹ Some Localities of Post-Tertiary and Tertiary Fossils in Massachusetts. *Am. Jour. Sci., Series III*, Vol. 36, pp. 56, 57.

1888. Though not recognizing the true nature of the material, he described a section of the Great Head Drumlin of Winthrop, a few miles northeast of Boston, and showed that beneath the great mass of clayey material, now known to be till, it possessed a core of fine loose gravel rising several feet above the base of the section (sea level), and containing fossil fragments of *Venus mercenaria* and other species identical with those existing in the waters of the harbor at the present time.

In 1888, Upham¹ also referred to the presence of the core of modified drift in the drumlin at Great Head, Winthrop, and announced the presence of similar cores in drumlins at Third and Fourth Cliffs at Scituate, some twenty-five miles southeast of Boston. No evidence as to age was brought forth beyond the fact that the stratified deposits were of glacial origin and antedated the ice advance, supposedly the last by which their till coating was deposited.

Shaler² was probably the first in Massachusetts to call attention prominently to the occurrence of two distinct tills separated by a long interglacial period. According to him the deposition of the oldest formation of Nantucket, which he describes as a blue pebbly clay till was followed by a long period of submergence and the deposition of fossiliferous marine beds, after which the ice again advanced, partly eroding the marine beds and giving rise to the well-known morainic deposits of the north shore of the island.

In his paper on the "Structure of Drumlins"³ Upham, in 1899, gave a detailed description of the drumlins of Third and Fourth Cliffs at Scituate and illustrated the descriptions by sections, one of which showed the presence of till both above and beneath the stratified core of the drumlins. The section apparently demonstrated that the stratified deposits were interglacial, at least in the narrow sense of the word, for they were evidently

¹ Marine Shells and Fragments of Shells in the Till near Boston. Boston Soc. Nat. Hist. Proc., Vol. XXIV, pp. 127-132.

² The Geology of Nantucket, U. S. Geol. Surv., Bull. 23.

³ Boston Soc. Nat. Hist., Proc., Vol. XXIV, pp. 228-242.

deposited between an earlier and a later ice advance. The two tills, however, were identical in character, and presented nothing indicative of any considerable time interval between their deposition. The tills and the included stratified drifts are probably to be regarded simply as marking local variations of the same general invasion. Drumlins in which layers of modified drift are inclosed in the till were also mentioned as occurring in other parts of Massachusetts and in New Hampshire and New York.

The descriptions of the drumlins at Scituate were repeated by Upham in 1894 in his paper on the "Madison Type of Drumlins,"¹ but no new facts of importance bearing upon glacial conditions in Massachusetts were presented.

In the table and descriptions accompanying his paper on the clays of Rhode Island and southeastern Massachusetts Woodworth,² in 1896, gave three glacial epochs. The first and second were separated by the deposition of the fossiliferous marine gravels, sands, and clays of the Sankaty sub-epoch, as was recognized by Shaler on Nantucket. The second ice invasion, which is apparently assumed (p. 977) as the cause of the strong folding of the Cretaceous, Tertiary, and early Pleistocene strata of Gay Head, etc., and the last invasion are separated by what is designated as the Vineyard interval of extensive subareal erosion, accompanied by deposition below the present sea level.

In the chapter on the clays about Boston, Marbut and Woodworth³ give reason for believing that the clays were probably of estuarine or marine origin, and were deposited in connection with a previous ice invasion. Several sections are described and illustrated which show that the clays are in a number of cases overlain by drumlins which were formed during the last ice advance. The clays frequently present evidences of strong erosion, probably due largely to the action of over-riding ice

¹ Am. Geol., Vol. XIV, pp. 69-83.

² The Glacial Brick Clays of Rhode Island and Southeastern Massachusetts: The Geology and Geography of the Clays. U. S. Geol. Surv., Seventeenth Ann. Rept., Pt. I, pp. 975-988.

³ Loc. cit., pp. 989-998.

(p. 991). According to the evidence presented, the clays are contemporaneous with an earlier ice advance, and are clearly older than the last, but nothing definite as to the length of time intervening is known.

In 1898, Shaler in his paper on "The Geology of the Cape Cod District,"¹ again recognized the existence of two tills, between the deposition of which a period of great length intervened. In this interval he recognized the deposition of three sedimentary formations:² the Nashaquitsa, the Barnstable, and the Truro, each of which was followed by prolonged periods of aqueous erosion. This interglacial time was regarded as vastly longer than that which has elapsed since the disappearance of the ice of the last invasion.

DESCRIPTION OF TILL EXPOSURES

The ordinary till exposures in southeastern Massachusetts present the following characteristics. At the top lies a light buff till consisting of the usual heterogeneous mass of clay, sand, and boulders. The percentage composition of this till varies within wide limits, especially in regard to the quartz-flour and clay constituents which range from a combined amount of perhaps 10 per cent. or less in some of the tills in the southern portion of the state to an average total of some 55 per cent. in the drumlins about Boston.³ In most sections the till is moderately oxidized from top to bottom, as indicated by its buff color, but where natural or artificial cuts have exposed it to any considerable depth it is found to pass downward into an unoxidized portion of a gray or bluish-gray color, usually designated as blue till. The depth to which the oxidation extends presumably depends somewhat on the percentage of the clay constituent of the till. Though the oxidation is very much less conspicuous in tills high in sand, the depth to which the oxidation extends is probably

¹ U. S. Geol. Surv., Eighteenth Ann. Rept., Pt. II, pp. 497-593.

² Loc. cit., pp. 535-538.

³ W. O. CROSBY: Composition of the Till or Boulder Clay. Boston Soc. Nat. Hist. Proc., Vol. XXV, p. 25.

greater than in the more clayey tills. In the Boston drumlins, which are high in clay, the oxidation has usually reached a depth of some twenty feet. Where the bedrock upon which the tills rest is exposed to view it is ordinarily found to present well glaciated surfaces, showing no traces of decomposition beyond a thin superficial zone seldom more than half an inch in thickness, and often represented only by a slight surface discoloration.

CENTER STREET EXPOSURE, BROCKTON

In marked contrast to the section just described are the sections exhibited by the older tills observed by the writer. The first of these old tills to be observed was exposed several years ago during excavations for the foundations of one of the heavy stone arch bridges which were necessitated by the abolishment of the grade crossings of the New York, New Haven and Hartford Railroad. (Fig. 2, Exposure 1.) The first six feet or so from the surface was of the ordinary slightly oxidized buff till of the last, or Wisconsin invasion, but on going deeper, instead of becoming lighter and gradually merging into the unoxidized blue till as in the ordinary typical section, the buff till gave place abruptly to a mass of distinctly red and yellow till. This till at the time it was seen by the writer was exposed to a depth of about four feet, but was later excavated to a depth of from two to four feet more, at which point it was found to rest on a deeply decomposed and highly oxidized conglomerate of Carboniferous age. Besides its high colors, due to the advanced state of oxidation, the lower till was found to differ in a marked degree in composition from the ordinary buff till. Clay, including quartz-flour, which in the overlying till forms less than one half of its bulk, constitutes nearly the whole of the lower till. The pebbles of the upper till comprise some 25 per cent. or more of its mass and are varied in type, complex in composition, fresh in appearance, and have often been transported considerable distances. In the lower till, on the other hand, the pebble component probably never exceeds 10 per cent. of the mass, and only the resistant quartz and quartzite pebbles from the underlying

rock are usually represented. The buff till is without visible structure, while the lower oxidized till is characterized by a distinct, but rude and highly irregular lamination.

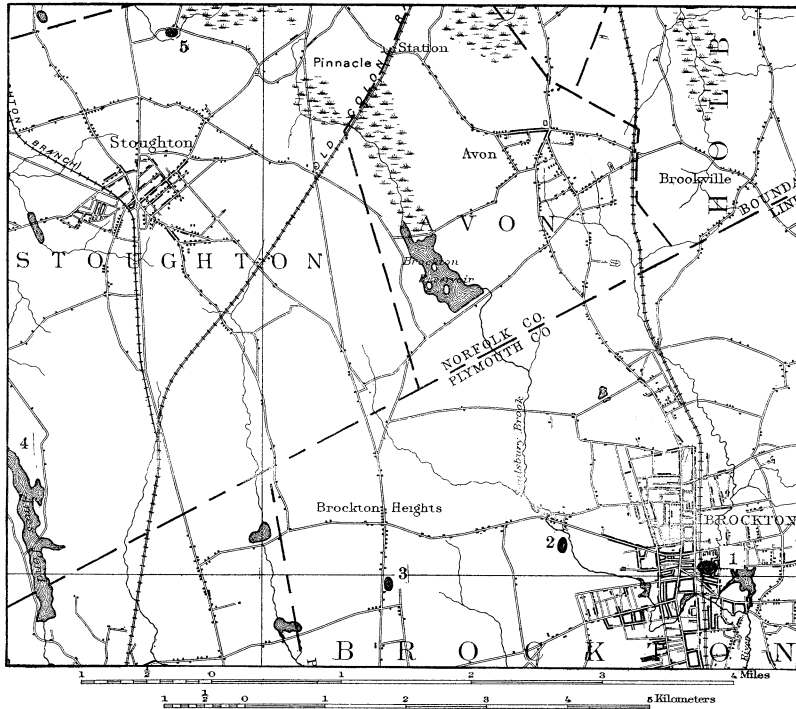


FIG. 2.—Map¹ showing location of exposures of tills of probable Pre-Wisconsin age. 1. Center street exposure, Brockton; 2. Intervale Park exposure, Brockton; 3. Pearl street exposure, Brockton; 4. Ames pond exposure, Stoughton; 5. Pine street exposure, Stoughton.

The derivation of the lower till from the underlying decomposed conglomerate is plainly indicated by its color and composition. This conglomerate is composed largely of pebbles of granite, black slate, quartzite, and some quartz,² embedded in a

¹ Reproduced from special edition of the Dedham quadrangle of the U. S. Geological Survey. Presented through the courtesy of Professor W. O. Crosby and the Boston Society of Natural History.

² Quartz also occurs in considerable amounts in the numerous small veins cutting the conglomerate.

somewhat feldspathic sandy matrix. It exhibits a rather perfect cleavage at right angles to its stratification. Where so situated as to be exposed to the full action of the ice at the time of the last invasion, it exhibits smooth, hard, and well glaciated surfaces of a dark gray color with almost no evidences even of superficial oxidation. In less exposed positions, such as exist along the well defined valley running southward through the city of Brockton just east of the center, the glaciation was apparently exceedingly slight. It is in such positions that the decayed conglomerate from which the lower till was derived is found. At the surface the conglomerate presents the high colors of advanced oxidation, but somewhat irregularly arranged owing to variations of the original composition of the rock. Some of the portions free from iron give on decay spots or streaks of an almost white sandy clay. The predominating color is a distinct yellow, interspersed with red in many places. The rock is so soft at the surface that it can sometimes be removed by pick and shovel. The depth of the extreme decay is somewhat variable, possibly averaging from two to three feet, though it is probably considerably greater in places. From the highly decayed portions, the rock passes downward by insensible gradations into less altered portions, but in none of the shallow excavations which the writer has seen has fresh rock, such as is exposed where the glaciation has been severe, been reached. The decomposed conglomerate probably underlies most of the low region near the center of the city and has been exposed in the laying of water pipes, drains, sewers, etc., along Center and Crescent streets and near the high-school building on Main street. Many of the excavations in which decomposed conglomerate was exposed were made ten or more years ago, and though the presence of the decayed rock can be vouched for, the writer cannot say with certainty that it was everywhere overlaid by the oxidized till, though later observations suggest that such was probably the case.

It is certain that the deep rock decay antedates the last ice invasion. If this decay is the result of pre-Pleistocene weathering,

the evidence naturally leads to the conclusion that the overlying oxidized till evidently derived from it was the result of the re-working of the soft decomposed material by the first ice advance, in which case it is probable that it should be correlated with the Kansan or pre-Kansan glacial deposits of the central portion of the country. If, on the other hand, the rock decay is considered as of interglacial origin it constitutes of itself an evidence of a long interglacial period. This last supposition, however, cannot be maintained, for the rock weathering is far too extensive, reaching downward as it does to a depth of some feet, to have been brought about in interglacial times.

An alternative supposition which naturally suggests itself is that the oxidized till may after all be considered as of Wisconsin age, and as representing the re-working of the pre-Pleistocene decomposed rock material which had somehow been preserved from the erosive action of the earlier invasions. In answer to this it may be urged that, while the actual erosive power of the earlier advance was comparatively slight, it is almost impossible to conceive of an ice sheet so weak that at a point more than fifty miles from its margin it passed over soft decomposed rock material without re-working it in any degree, especially as till deposits of the corresponding advance occur along the outer margin at Nantucket sixty miles further south. A further and apparently fatal objection to the consideration of the oxidized till as of Wisconsin age lies in the fact that, in the re-working of the previously decayed rock and soil by a sheet known to be specially characterized by numerous foreign fragments, there would at least be a gradual transition between the highly oxidized and the ordinary type of till. In reality, however, the contact is so sharp that the breadth of a hand will usually, and sometimes more than cover it.

INTERVALE PARK EXPOSURE, BROCKTON

At the time of the laying out and leveling of the tract of land known as Intervale Park, about a mile west of the Center street locality, a number of good sections of till were transiently

exposed. One of these sections (Fig. 2, Exposure 2) showed a yellow and red oxidized till, almost identical in appearance with the one previously described and lying in a corresponding position beneath the ordinary buff till. The general character of the exposure is shown in Fig. 3, in which the horizontal and vertical scales are the same.

In composition the lower till was similar to that of the Center street exposure, being probably as high as 70 or 80 per cent. in clay and quartz flour. Like the first, it was evidently derived from the underlying conglomerate and showed the same quartzite pebbles and the same yellow and red colors. The prevailing

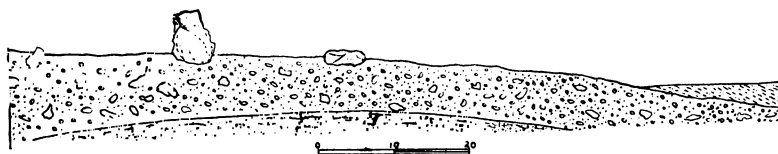


FIG. 3.—Section showing the relations of the older and younger tills in the Intervale Park exposure, Brockton. (Exposure 2 of Fig. 2.)

color, however, was somewhat lighter, yellow and gray predominating. Like the Center street exposure it was irregularly laminated and separated from the overlying till by a sharp and distinct line of demarcation.

With a view to comparing with other tills, samples of the oxidized till were collected and examined as to their composition. In the following table the results of the examination are given and compared with the immediately overlying till, and with the till of drumlins in the vicinity of Boston:

					Boulders and gravel	Sand and quartz flour	Clay
1. Highly oxidized clay-till ¹	-	-	-	-	10	68	21-23
2. Ordinary till overlying the above ²	-	-	-	-	50	45	5
3. Clay-till of Boston drumlins ³	-	.	-	-	25	63	12

Attention is especially called to the clay constituent which in the lower till is about four and a half times as great as in the

¹ Clay determined chemically, others estimated from physical examination.

² Estimated from physical examination.

³ Average of sixteen careful physical analyses by W. O. CROSBY, Boston Soc. Nat. Hist., Proc., Vol. XXV., p. 124.

overlying till and nearly twice that of the tills of the drumlins, which represent the most clayey tills previously known. The difference in the amount and character of the included rock material is also very marked. The lower till was found to contain only about 10 per cent. of pebbles, mainly under an inch in diameter and consisting principally of quartzite. The upper till contained some 50 per cent. of pebbles and cobbles, besides a large number of massive boulders of granite and diorite varying from five to ten or even twenty feet in diameter.

The underlying rock was not exposed in the immediate vicinity of the till here described, but it is known to be a conglomerate similar in character to that of the Center street locality, and to be likewise considerably decomposed.

The great dissimilarity of the lower till from the overlying till, the sharp line of demarcation between the two, the evident derivation of the former from deeply decomposed conglomerate, and the exceptionally close resemblance of the lower till to that of the Center street exposure, have led the writer to correlate it with the latter and to refer it to the same early Pleistocene invasion.

PEARL STREET EXPOSURE, BROCKTON HEIGHTS

The writer's attention was called to this exposure of what may probably be considered as a representative of pre-Wisconsin till by Mr. M. S. W. Jefferson, of Brockton, to whom the credit of the discovery of the locality is due. The exposure was within a gravel pit of some size on the south side of Pearl street, a short distance north of its junction with Rockland street (Fig. 2, Exposure 3).

The height of the section was about five feet, of which the upper two feet was of the ordinary type of buff till containing numerous boulders. The lower three feet was of an entirely different and somewhat remarkable character, being composed of an arkose-like mass of disintegrated material evidently derived from the coarse porphyritic granite which is known to underlie it. At first sight it bears a slight resemblance to a granite disintegrated *in situ*, but a closer examination reveals the presence

of sand and pebbles of foreign material, showing that it is to be regarded as a true till in which, as in the two tills already described, the material is almost entirely derived from the underlying rock. The color of the mass is a dirty, somewhat rusty brown, there being no trace of the higher colors exhibited by the tills previously considered. The line of demarcation between the two tills is much less sharp than in the preceding instances and is due to the predominance of the same granitic material in both tills. The chief difference is that in the lower till the granite is present as a disintegrated arkose-like mass, while in the

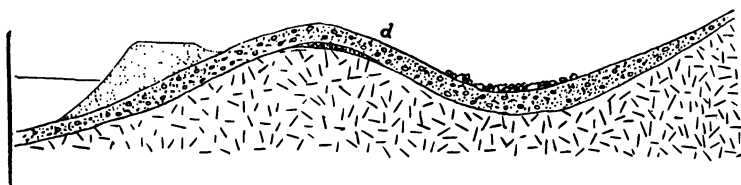


FIG. 4.—Section showing general relations of granite, till, and drift terrace at the Ames Pond exposure, Stoughton. Vertical scale, about 200 feet to an inch; horizontal scale, about 50 feet to an inch.

upper till it occurs in a fresh condition and largely as glaciated pebbles or boulders.

AMES POND EXPOSURE, STOUGHTON

This exposure is in a gravel pit on the east side of the pond north of the small bay which comes up to the highway (Fig. 2, Exposure 4). The general section of the locality is shown in Fig. 4. The till to be described is exposed on the east slope of the rock and till ridge at *d*.

The lower till is somewhat similar to that in the Pearl street exposure at Brockton Heights, the material being a pink granite. The chief point of difference, perhaps, lies in the fact that the till of the Ames Pond exposure appears to have been originally a bowldery till, the fragments of which in most cases have subsequently completely disintegrated. The disintegrated granitic material probably constitutes ninety or ninety-five per cent. of the mass, and is apparently of local origin since a knob of similar granite projects through the till a short distance to

the north. There are a few pebbles of a fresher, though still distinctly weathered granite dispersed sparingly in the till. The difference in the extent of the decay is probably to be explained by the fact that the process which subsequently brought about disintegration were, in the larger portion of the material, well under way at the time of the ice advance, though actual disintegration may not have taken place until long afterwards. The fresher fragments were probably derived from portions of the ledges from which the more highly decomposed material had previously been removed. The thickness of the lower till as exposed in the gravel pit is about four or five feet. The color of the till is slightly darker than the overlying buff till, but the distinction is not marked.

The upper till is composed of a heterogenous mass of material in which the same pink granite predominates, but with a considerable intermixture of foreign material. Its line of demarcation from the lower till is well defined, but, as would be expected from the fact that granite is the predominating material in both cases, is not so sharp as in the first two of the Brockton tills. All fragments of the upper till are fresh and usually present well glaciated surfaces.

PINE STREET EXPOSURE, STOUGHTON

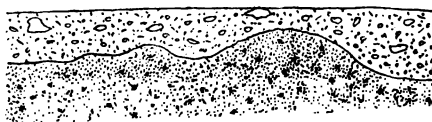
The gravel pit in which was found the last of the tills to be described is located on the south side of Pine street at its junction with Pleasant street near the northern boundary of the town (Fig. 2, Exposure 5). The cut was about fifteen feet deep at the time it was seen by the writer. Two tills were distinctly exposed in the section, the relations of which are shown in Fig. 5.

The lower till, as in every case which has been described, is very homogeneous in composition. In this instance it is composed largely of the disintegrated material of a biotitic and hornblendic syenite, the source of which is probably close at hand. There is a slight admixture of foreign material but probably not more than 5 per cent. As in the case of the Ames

Pond exposure the till appears to have been originally composed largely of bowlders, the decay of which was well under way at the time of the laying down of the till, but which did not completely disintegrate until some time afterwards. Some of the larger bowlders still show undecomposed cores, but as a rule the disintegration is complete. The color is rather a dark brown, somewhat similar to the reddish-brown color of decomposed diabase, and serves to sharply separate the lower from the upper till.

The upper till is of the ordinary heterogeneous type abounding in foreign fragments, many of them rather far-traveled. There is proportionally little of the dark syenite in the upper till, differing in this respect from the Pearl street and Ames Pond exposures in which the predominating material of both tills is the same. When present in the upper till the syenite is fresh.

In the case of the Center street and Intervale Park exposures of Brockton the reasons have been given for regarding the tills as probably representing the earliest of the Pleistocene advances. One of the most prominent of these reasons, namely, the position of the till upon deeply decayed and unglaciated rock surfaces, cannot be applied with certainty to the last three tills described, since the immediately underlying rock is not exposed and its condition is not known. The difference in the colors is also a noticeable feature, the granite and syenite tills showing nothing of the high colors which characterize the tills derived from the conglomerate. A study of granites decayed *in situ*, however, shows that high colors are not the necessary accompaniment of disintegration such as the granite of the tills has undergone. The same close dependence of composition upon the underlying or immediately adjacent rock, the same small percentage of foreign material, the same highly weathered



Vertical and horizontal scale : 1 in. = 30 ft.

FIG. 5.—Section showing the relations of the older and younger tills in the Pine street exposure, Stoughton. (Exposure 5 of Fig. 2.)

character, and the same distinct or even sharp division from the overlying tills, all seem to point to an origin similar, and probably contemporaneous with that of the Brockton tills. The deposition of the tills is believed to date from the time of earliest Pleistocene ice advance.

POSSIBLE INTERGLACIAL ROCK DISINTEGRATION

A further reason for considering the tills composed of highly oxidized or disintegrated material as representing the first ice invasion lies in the fact that the weathering is distinctly more advanced than in the exposures of what seems likely to prove to be examples of interglacial weathering. It has been seen that at the advent of the first ice sheet the rocks of the region were deeply decomposed as, for example, the conglomerate at Brockton. It is also known that where the conglomerate was so situated as to receive full benefit of the erosive action of the ice of the last advance the ledges are perfectly fresh. Between these two extremes there are numerous examples of a partial breaking up of the ledges by atmospheric agencies, and a partial disintegration. Such a case is illustrated in Fig. 6.

The moderate amount of decay exhibited by ledges of this class, as compared with ledges known to be pre-glacially decomposed, or with tills formed from such decomposed material, and the considerable amount which they show as compared with the freshly glaciated ledges of the last ice advance, seem to make a plausible case in favor of the view of interglacial weathering. In this case we have a rough measure of the time from the earliest of the Pleistocene ice advances to the present time, for both the field relations and weathered character show that the conditions mainly antedate the last of the ice invasions. The evidence of this weathering, if it be accepted as interglacial, is indicative of the great length of such time as compared with that which has elapsed since the final disappearance of the ice.

The preservation of these ledges evidently depended in many cases upon the character of the topography, but this is not always the case. The general explanation probably lies in the

fact that all of the occurrences noted lie in the southern belt, in which, with the exception of the hills and other prominences, the work of the ice of the last invasion was largely one of deposition.

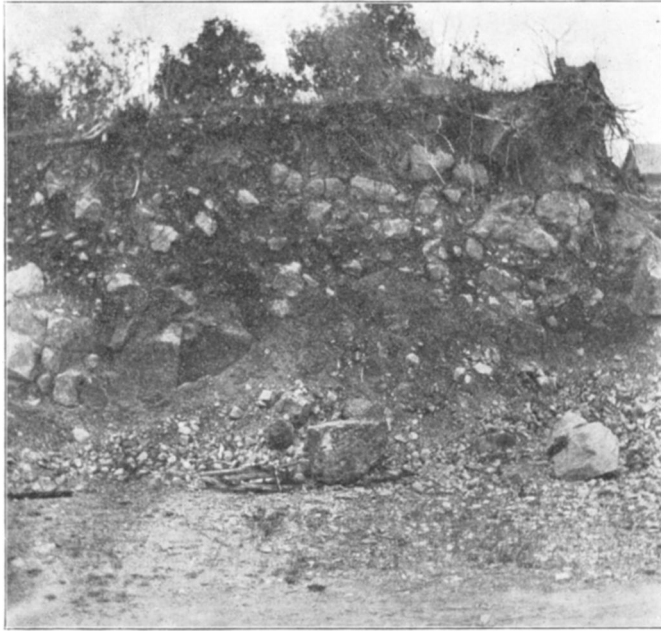


FIG. 6.—View of disintegrated ledge of conglomerate, Intervale Park, Brockton. The weathering is supposed to be interglacial in age.

SUMMARY AND CONCLUSIONS

1. The Pleistocene ice sheet on its first advance found a somewhat deeply decayed rock surface, many remnants of which are now to be seen.
2. The erosive power of the first advance was not sufficient to entirely remove the products of decay, for tills evidently composed of such products have been found by the writer beneath the ordinary tills of the region. These have been described in this paper.
3. The older tills are probably the result of the re-working of

pre-glacially decomposed rock and its accompanying soil, rather than by the process of accretion, by which many of the later deposits of till, such as drumlins, etc., were built up.

4. The remnants of the early till are characterized by (*a*) the presence of 20 per cent. or more of clay, (*b*) the presence in some of the tills of 10 per cent. or less of pebbles, (*c*) a composition which is dependent almost entirely upon the underlying or immediately adjacent rock, (*d*) the decayed or disintegrated character of its materials, (*e*) the presence of colors characteristic of high oxidation, (*f*) its position in certain cases upon deeply altered and practically unglaciated rock surfaces, and (*g*) its distinct line of demarcation, both as to color and composition, from the overlying till.

5. The upper till, on the other hand, is characterized in the region under discussion by (*a*) the presence of probably less than 5 per cent. of clay, (*b*) the presence of 40 to 50 per cent. of rock fragments, (*c*) a composition often largely independent of the immediately underlying rock and including numerous far-traveling erratics, (*d*) slight oxidation, and (*e*) by its unweathered and distinctly glaciated fragments.

6. No evidences of a soil zone between the two tills have so far been observed.

7. It seems probable that there were comparatively few localities in which the highly oxidized tills remained at the time of the last invasion, for otherwise there should be more traces of oxidized material, especially the colored clays, in the later till. The early tills were probably largely eroded during the later stages of the same ice sheet by which they were formed.

8. The action of the ice of the last advance in many cases was to cover the earlier till remnants by a new coating of till, and was protective rather than erosive in its nature.

9. Nothing indicative of more than two general periods of glaciation has been noted by the writer. The position of stratified deposits between two tills identical in character, and of the Wisconsin type, is probably to be explained as resulting from

the overriding of deposits laid down during a temporary retreat or local recession of the ice of the same general invasion.

10. The post-glacial weathering is in general confined to a slight oxidation of the till, the wearing of the pebbles, boulders, and glaciated ledges being usually limited to a slight superficial decay or a mere discoloration of the surface.

11. There are numerous exposures showing rock disintegration of a type intermediate between the high decay characteristic of the pre-Pleistocene weathering and the slight weathering of post-glacial times. This disintegration is believed to have taken place largely in interglacial times.

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